A hardware-software complex for modelling and research of near navigation based on pseudolites

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A hardware-software complex for modelling and research of near navigation based on pseudolites

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Abstract. The paper considers a hardware-software complex for research of characteristics of accuracy and noise immunity of a near navigation system based on pseudolites. The complex is implemented on the basis of the “National Instruments” hardware platform and “LabView” coding environment. It provides a simulated navigation field, the analysis of the received signals, the determination of the errors of measurement of navigation parameters for pseudolites signals, comparing the measured error with the characteristics of a standard GNSS receiver.

1. Introduction

Currently, a near navigation system is widely adopted technologies based on the use of pseudolites [1–3]. In such systems, the measurement of navigation parameters is carried out basing on signals pseudolites. Their structure is similar to that of signals from navigation satellites GLONASS / GPS. The main advantages of near navigation systems based pseudolites are an opportunity to improve the geometric factor, the formation of high-power signals. The result is the accuracy of the navigation determinations system and improved noise immunity.

Despite all the advantages of navigation systems based on pseudolites, there are a number of unsolved problems [4–8]:

1. An increased pseudosatellite signal level requires an enhanced dynamic range of the navigation receiver.
2. Multipath pseudolites navigation signal error increases with code and phase measurements of navigation parameters.
3. Great synchronization errors of time scales accuracy of pseudolites lead to deterioration in the accuracy of navigation determinations.
4. Weak electromagnetic compatibility of signals pseudolites and navigation satellites.

Solving these problems requires further theoretical and experimental studies. This leads to the creation of the hardware-software complex - an experimental prototype of the near navigation system based on pseudolites.

2. Requirements for the hardware-software complex

Basic requirements for the hardware-software complex are formed based on the navigation structure of the system, in which the main element is a grouping of pseudolites. The structure of the hardware-software complex should include pseudolites prototypes for forming the navigation field with the specified parameters. Thus, it should provide [7–9]:

- determination of the accuracy characteristics of navigation parameters measurement methods;
- analysis of the noise immunity of the receiver pseudolites signals;
- the ability of flexible changes of parameters of pseudolites signals;
- the ability to control the geometric factor of pseudolites grouping.
- flexible management of all components of the hardware-software complex.

3. The structure of the hardware- software complex

As a result of analysis of possible options of the construction of hardware systems for the study of such systems [10–12], a variant of creation of the hardware-software complex, based on hardware platform National Instruments and software LabVIEW, was suggested. In addition, it should provide for the possibility of using test equipment from other manufacturers, and a specialized software.
Based on these requirements, the block diagram of the hardware-software complex was developed (Figure 1).

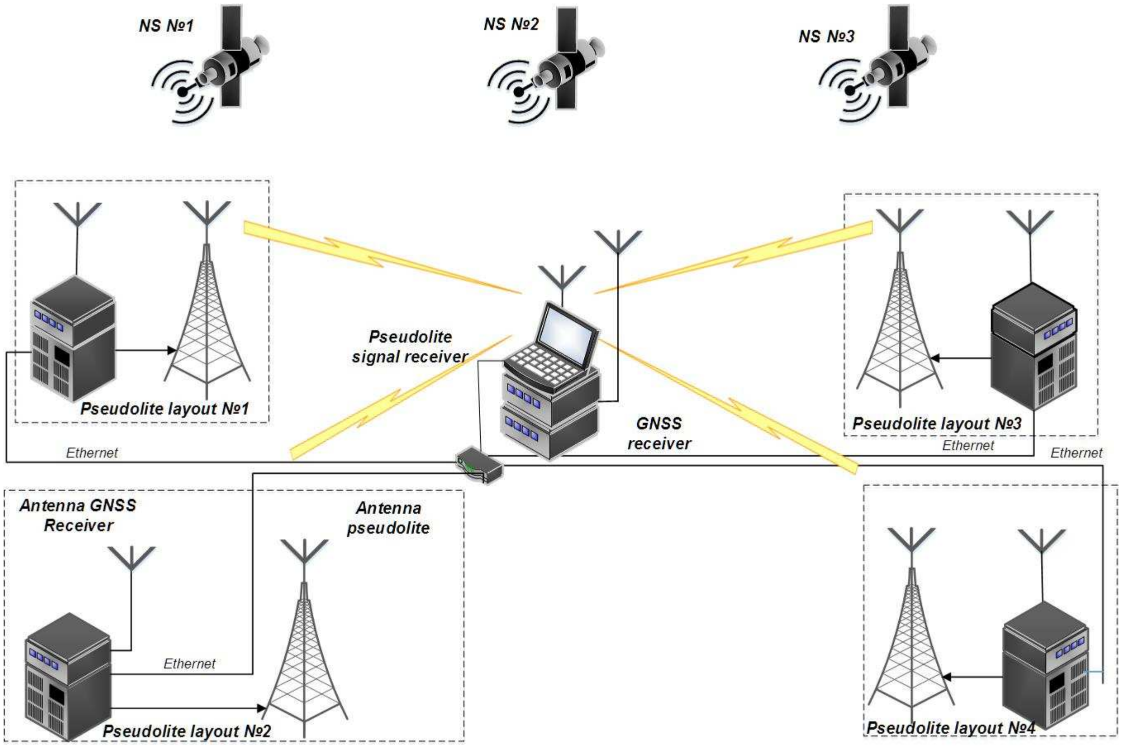

Figure 1. The structure of the hardware-software complex for modeling and researching the systems of near navigation on the basis of pseudolites

Its structure consists of the following parts:
- four pseudolites layouts;
- receivers of pseudolites signals and satellite navigation signals, connected to a receiving antenna;
- a portable signal analyzer;
- personal computers for processing of experimental results.

The main task of the hardware-software complex is the formation of an artificial navigation field in a given region of space. This task is performed by four pseudolites layouts that emit navigation signals of the required structure. Transmitting antennae of pseudolites have accurate geodetic reference to the terrain. The exact coordinates of the pseudolite antenna are included in its navigation message and are used in the solution of the navigation task in the receiver.

4. The operating principle of components of the hardware-software complex

The basis of the pseudolite layout is a hardware platform “PXI” of National Instruments Company, which operates under the control of software LabVIEW. A pseudolite layout consists of the following components (see Figure 2):

- Vector generator of signals NI PX1e-5673E;
- RF attenuator NI PXI-5695;
- Computer controller NI PXIe-8880;
- Chassis NI PXIe-1085;
- GNSS receiver (such as MRK-101).

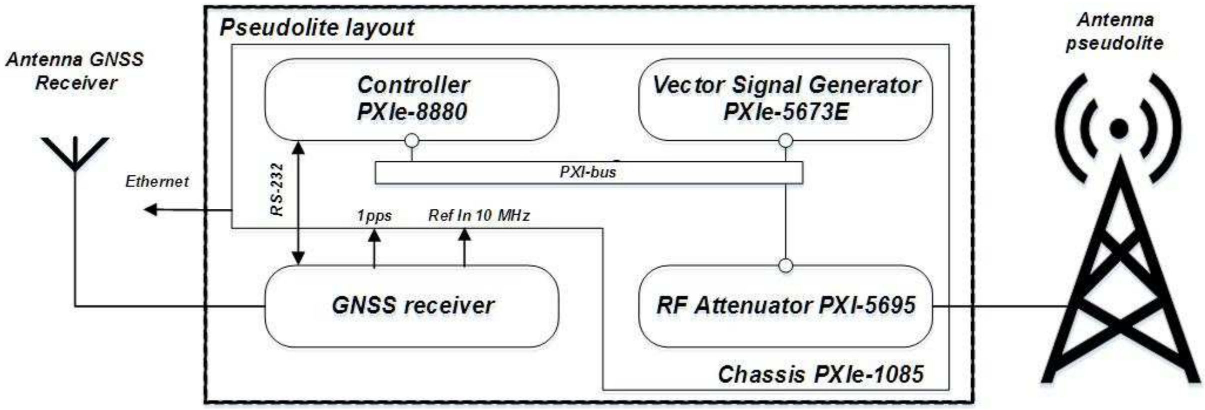

Figure 2. A block diagram of the pseudolite layout

The navigation signals are generated by vector generator NI PXIe-5673. Modern technologies used in the vector generator, allow arranging the full direct digital synthesis in the formation of radio signals. Vector Generator NI PXIe-5673 consists of three functional modules: a signal generator of the arbitrary waveforms “NI PXIe-5450”, HF generator “NI PXI-5652” and a vector modulator “NI PXIe-5611” (Figure 3).

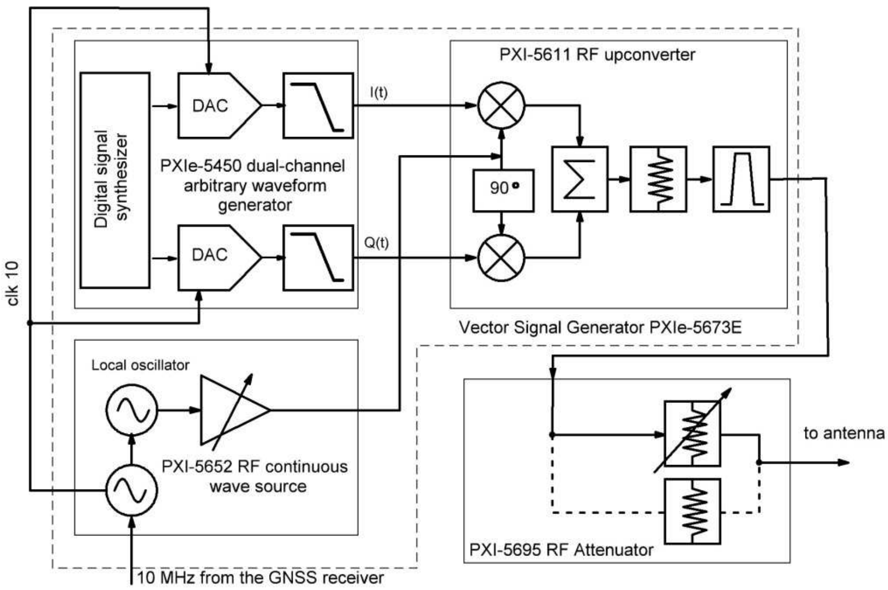

Figure 3. A functional scheme of the pseudolite layout based on vector generator PXIe-5673

The digital signal synthesizer, located in arbitrary waveform generators NI PXIe-5450, is formed by a digital code in phase I (t) and quadrature Q (t) components of the modulating sequence of the navigation signal. This code is generated by the algorithm specified in special software module (subVI) LabVIEW. By changing the algorithm, it is possible to create a variety of the navigation signal structures and explore their effectiveness.

The digital code of the modulating sequence of the navigation signal is converted into an analog signal DAC. Phase and quadrature components of the analog signal from the DAC output are filtered by a low-pass filter (LPF) and arrive at the output of the generator of the arbitrary waveform signal. Thus, the output of NI PXIe-5450 formed modulating sequence corresponding to the structure of the navigation signal.

In vector generator NI PXIe-5673 of signals, direct transfer of signals from the baseband to an RF band is applied. The inputs of vector modulator NI PXIe-5611 receives phase and quadrature components of the modulation signal sequence and navigation RF signals at the carrier frequency with HF generator NI PXI-5652.

In vector modulator NI PXIe-5611 there is a transfer of in-phase and quadrature components of the navigation signal to the frequency of pseudolite radiation. In addition, the formation of an integrated navigation signal, its amplification and filtering within the necessary bandwidth occur. As a result, the output of the vector modulator (it is the output of the vector generator) enters the high-frequency navigation signal in the band specified frequency code channel.

To solve the problem of the navigation provision of users, similarly to GNSS, the time scales of pseudolites are to be synchronized and their signals - coherent. The peculiarity of the formation of a highly coherent navigation pseudolite signal is to synchronize all functional units of the vector generator by means of the highly stable reference signal of 10 MHz from GNSS receiver MRK-101.

Permissible relative error of the reference signal in frequency in the mode of GNSS receiver tracking after the signals of navigation satellites is less than $\pm 3 \cdot 10^{-10}$. The generator of pseudolite time scale synchronizes all the functional components of the vector generator: RF generator oscillator NI PXI-5652, a digital signal synthesis scheme, the DAC and other nodes requiring synchronization. If necessary, synchronization vector generator signals can be realized by the highly stable time and frequency standard.

To extend the range of power variation of the output signal, two-channel programmable RF attenuator NI PXI-5695V was introduced in the pseudolite scheme. When maximum power of the output signal of the vector generator is equal to 10 mW, HF attenuator allows changing the power of the signal at the output of the pseudolite in the range of 1 mW to 10 mW. This wide range of changes in signal strength will allow investigating the effect of the signal power level of the reliability of navigation definitions under the impact of noise and assessing the sensitivity of the receiving devices. If we take the values of the gains of the receiving and transmitting antennas to be equal to 3 dB, we can determine that the signal level with a power of 1 mW to 10 mW will provide an opportunity to carry out experimental research at a distance of 500 m to 50 km from the pseudosatellite layout, when the signal level at the receiver input is161 dBW.

The hardware-software complex allows carrying out experimental studies with different types of radiated signals. Since vector signal generator NI PXIe-5673 can generate signals in the range from 85 MHz to 6.6 GHz, and the LabVIEW software environment allows generating any code signal structure, then, at the pseudosatellite layout output, it is possible to obtain signals both with frequency and code division.

Values of signal frequencies emitted by pseudolites layouts are selected in the operating range of the standard frequency of the GNSS receiver. However, to eliminate the mutual influence of the GLONASS signals and the signals from the pseudolites layout, the signal frequencies of the latter are formed in the frequency band free from standard satellite signals. Figure 4 shows the frequency bands for signals pseudolites layouts in the L1 band. Frequency bands for their performance in the range of L1 are equal to 1593…1598 MHz and 1605…1610 MHz, the width of each band is 5 MHz. In this frequency band, it is possible to form up to 16 frequency channels. Selection and distribution of frequencies for band L2 can be produced in a similar manner. In this case, the range of signal emission of the pseudolites layouts will be within 1238…1243 MHz and 1248…1253 MHz.

The configuration of location of pseudolites layouts and their number in the near navigation system under development depend on the terrain and the size of the area where the navigation provision is required. Using the hardware-software complex will provide practical experimental data of dependence of to the geometric factor on the number of pseudolites layouts and their relative position. This will allow calculating the potential accuracy of coordinates measurement, the accuracy of determining the spatial position of the consumers of navigation information, as well as the performance of the noise immunity of consumers of the developed near navigation system.

To reduce the error associated with multipath signals of navigation in difficult terrain conditions, it is advisable to use a directional antenna with the directional diagram of a special shape as a transmitting antenna in order to create the required navigation field.

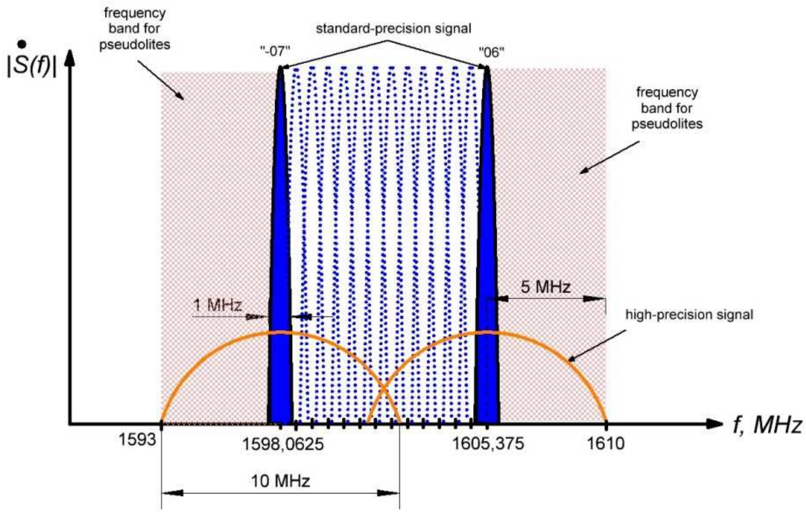

Figure 4. Distribution of frequency signals for the pseudolites layouts for the L1 band

5. The methodology of the research with the help of the hardware-software complex

Two measuring receivers are placed on the ground: angle GNSS receiver (of MRC-101 type) and a finished signal receiver of pseudolites connected to the same antenna. Pseudolites frequency signals are in the operating range of the GNSS frequencies. If possible, it is advisable to carry out topographic binding of the pseudolite antenna to the points of the state geodetic network.

Received and processed navigation information from two receivers is supplied via communication lines for data processing to the PC. Then, using special software, the processing of the experimental data, calculation of measurements errors under different external conditions: changing of the geometric factor and power signals of pseudolites layouts, application of navigational signals of various types, under the influence of interference.

To measure the level of the received navigation signal, a signal analyzer is connected to the input of the reception path through the directional coupler.

The means of the hardware and software complex make it possible to evaluate the measurement error of navigation parameters for pseudolites signals by comparing the coordinates obtained from the GNSS receiver and from other sources under the impact of various external factors.

6. Conclusion

The proposed version of the hardware-software complex provides large-scale opportunities for modeling and researching the systems of near navigation on the basis of pseudolites. This complex allows us to estimate the validity of selection of the navigation signal parameters, optimum geometrical arrangement of pseudolites, efficiency of the developed receiver processing algorithms at the stages of designing. A special software will allow us to automate the process of measuring the accuracy of the navigation options, to explore the noise-immunity of the developed near navigation system.

7. Acknowledgments

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References

[1] Kim C., So H., Lee T., Kee C. 2014 A pseudolite-based positioning system for legacy GNSS receivers. *Sensors (Switzerland)*. **14 (4)** 6104-6123
[2] Rzepecka Z., Rapiński J., Cellmer S., Chrzanowski A. 2014 Effect of additional distance measurements on satellite positioning. *Acta Geodynamica et Geomaterialia*. **11 (1)** 35-44
[3] Xu R., Chen W., Xu Y., Ji S. 2015 A new indoor positioning system architecture using gps signals. *Sensors (Switzerland)*. **15 (5)** 10074-10087.
[4] Wan X., Zhan X. 2012 The research of multipath and linear error for pseudolites applications. *Applied Mechanics and Materials*. **130** 2890-2893
[5] Shen L., Li L., Zhang H., Bao T. 2015 A near-far effect mitigation method of pseudolites based on array signal. *Lecture Notes in Electrical Engineering*. **340** 647-656
[6] Alexandru R.-C., Elena-Simona L. 2015 Comparison of detection techniques for multipath propagation of pseudolite signals used in dense industrial environments. *Energy Procedia*. **100** 1294-1300
[7] Liu C., Lin P., Zhang J., Zhao X. 2015 An improved pseudolite location model of GPS/pseudolite integrated positioning. *Zhongguo Kongjian Kexue Jishu/Chinese Space Science and Technology*. **35 (1)** 75-83
[8] Sultana Q., Sarma A., Kumar A., Malik M. 2012 Enhancement of DOP in stratolite-based navigation systems. *IETE Journal of Research*. **58 (6)** 476-482
[9] Borsoev V.A., Galeev R.G., Grebennikov A.V., Kondratiev A.S. 2011 *Scientific Bulletin MSTU CA*. **164** 17-23
[10] Krasnenko S.S., Pichkalev A.V. 2011 *Reshetnev Readings: Materials of the XV International Scientific Conference*. **2** 184-185
[11] Krasnenko S.S., Pichkalev A.V., Nedorezov D.A., Lapin A.Yu., Nepomnyashchii O.V. 2014. *Vestnik SibSAU*. **1 (53)** 30-34
[12] Dmitriev D.D., Gladishev A.B., Tyapkin V.N., Fateev Yu.L. 2016 Hardware-Software Complex for Studying the Characteristics of GNSS Receiver. *International Siberian Conference on Control and Communications (SIBCON)*